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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 5 : G01S 17/08, 17/88, 17/50

A2

(11) International Publication Number: WO 90/12330

(43) International Publication Date: 18 October 1990 (18.10.90)

(21) International Application Number: PCT/GB90/00567

(22) International Filing Date: 12 April 1990 (12.04.90)

(30) Priority data:
8908375.2 13 April 1989 (13.04.89) GB

(71) Applicant *(for all designated States except US)*: MEASUREMENT DEVICES LIMITED [GB/GB]; Silverburn Crescent, Bridge of Don Industrial Estate, Aberdeen AB2 8EW (GB).

(72) Inventor; and
(75) Inventor/Applicant *(for US only)* : BALL, Steven [GB/GB]; Knockhill Farm, Strachn, Banchory, Kincardineshire (GB).

(74) Agent: FITZPATRICKS; 4 West Regent Street, Glasgow G2 1RS (GB).

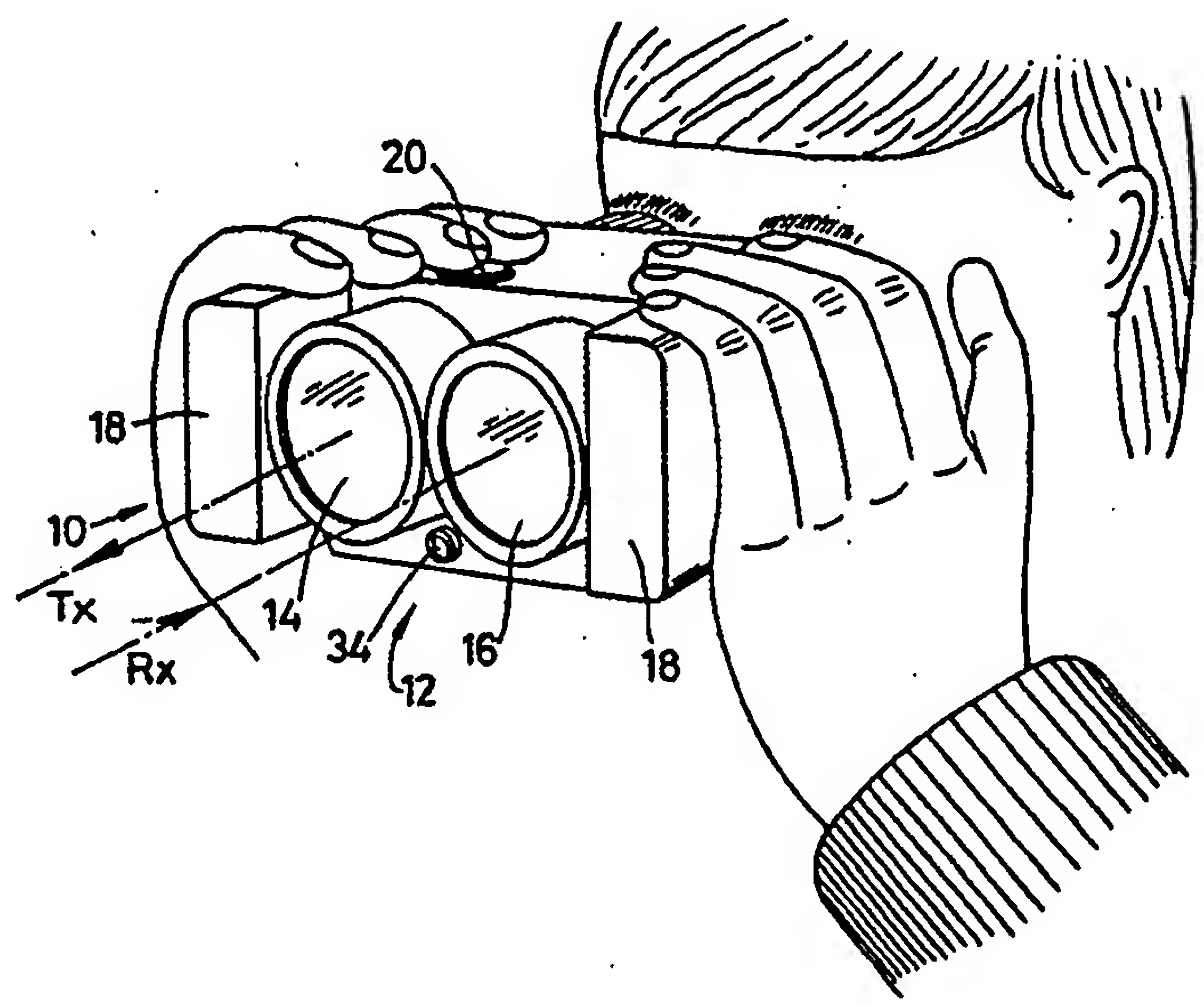
(81) Designated States: AT (European patent), AU, BE (European patent), CA, CH (European patent), DE (European patent), DK (European patent), ES (European patent), FR (European patent), GB (European patent), IT (European patent), JP, LU (European patent), NL (European patent), SE (European patent), US.

Published
Without international search report and to be republished upon receipt of that report.

(54) Title: HAND-HELD LASER RANGEFINDER

(57) Abstract

A hand-held, "time-of-flight" laser rangefinder comprises a main body (10) enclosing the rangefinder laser transmission and detection optics (14, 16) with battery holders (18) disposed on either side acting as hand-grips. An electronics housing (12) disposed on the underside of the body (10) incorporates an alphanumeric display and a keypad, and encloses microprocessor and memory means for controlling the operation of the device and data logging. One embodiement, intended for use in surveying applications, further includes an inclinometer for measuring the angle of the optical axis of the device with respect to the horizontal, the memory means being adapted to log distances and corresponding angles for a plurality of readings. A further embodiment is adapted to measure the speed of moving objects from the change in distance and the elapsed time between successive readings taken from the object. A data down-load port (34) is also included to allow data to be output to a computer, printer etc. for further analysis, hard copy etc.



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"HAND-HELD LASER RANGEFINDER"

The present invention concerns a laser rangefinder which is self-contained and of a size and weight suitable for hand-held use. One embodiment of the invention is intended for survey applications (particularly the surveying of rock faces, but also in road construction, mining, forestry, hydrography and off-shore operations), whilst a second embodiment is adapted to measure the speed of moving bodies, such as motor vehicles.

Laser rangefinders are known which are based on the "time of flight" of a laser pulse reflected from the target object, comprising a laser source and a detector, wherein the distance to the target is computed by measuring the time interval between transmission of the laser pulse and detection of the reflected signal. The distance to the target equals the time interval multiplied by the speed of light, divided by two. One such device is utilised in the "Quarryman" (Trade Mark) rock face survey system by Measurement Devices Limited. This system comprises a laser rangefinder mounted in a rotatable yoke, and further includes sensors for measuring the vertical inclination and horizontal angles for an array of points, an entire rock face can be surveyed from a single position, and the survey data can be used in conjunction with intended and/or actual borehole positions to determine burdens etc for blasting operations.

The "Quarryman" equipment is relatively bulky and expensive, has to be tripod-mounted in use, and requires a external electronic data-logger and power supply. One object of the present invention is to provide a rangefinder device capable of performing similar survey functions to such existing survey equipment, but which is substantially more compact, less expensive, and capable of hand-held operation.

A further object is to provide a hand held laser rangefinder, of a similar type, adapted to measure the speed of moving targets.

Accordingly, the invention provides a laser rangefinding device, comprising a self-contained unit consisting of a laser

for transmitting a laser signal towards a target, detector means for detecting the reflection of said signal from the target, microprocessor means for measuring the elapsed time between transmission of the signal and detection of the reflected signal and for calculating the distance of the target from the device, memory means for storing a plurality of calculated distances and other data associated therewith, optical sighting means for aligning the laser signal axis with the target, input means for inputting reference data relating to the measured distances, and visual display means for displaying measured distances and other data, the unit being of a size and weight suitable for hand-held use.

In an embodiment of the invention particularly intended for survey applications, the device further includes an inclinometer for measuring the inclination of the device to the horizontal, and the memory means is adapted to store the inclination associated with each measured distance. In this case the input means preferably allows the input of reference data relating to the subject being surveyed and the height at which the device is held in use.

In an alternative embodiment particularly intended for measuring the speed of moving targets, the device further includes means for measuring the elapsed time between successive distance measurements taken from a target, and calculating the speed at which the target is moving from the difference between the two measured distances and the elapsed time therebetween.

The device preferably comprises a main body portion incorporating the laser, detector and sighting means, and including a transmitter lens, associated with the laser, and a receiver lens, associated with the detector, disposed side-by-side, with battery housings adapted to receive batteries to power the device located on either side of the lenses and adapted to constitute hand-grips.

The data input means is preferably a keypad which, together with the visual display, is located on the underside of the main body portion. In the survey device, the inclinometer s preferably an electrolytic liquid level sensor,

and is also contained in the housing.

The sighting arrangement preferably includes an eyepiece located in a rear surface of the main body portion, and adapted to sight through the transmitter lens along the signal axis.

A second visual display is preferably also provided which is visible through the sighting eyepiece.

Embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Fig. 1 is a front perspective view of a device embodying the invention in hand-held use;

Fig. 2 is a bottom perspective view of the device of Fig. 1;

Fig. 3 is a schematic illustration of the rangefinding and sighting optics of the device;

Fig. 4 is a schematic block diagram illustrating the connection of various components of the device;

Fig. 5 is a drawing illustrating the use of the device in surveying a rock face for blasting operations;

Fig. 6 is a computer generated isometric view of a rock face created from data collected using a device such as that disclosed herein;

Fig. 7 is a collection of computer generated horizontal cross-sections of the face of Fig. 6;

Fig. 8 is a collection of computer generated vertical cross-sections of the face of Fig 6;

Fig. 9 is a computer generated isometric view of a stockpile created from data using a device such as that disclosed herein; and

Fig. 10 is a plan contour plot of the stockpile of Fig. 9.

Referring now to the drawings, a laser rangefinding device embodying the invention comprises a main body portion 10, and an electronics housing 12 located on the underside thereof. The body portion 10 includes a casing enclosing the laser and detector of a "time-of-flight" laser rangefinder, and its transmission and detection optics. Transmitter and

receiver lenses 14 and 16 are positioned side-by-side at the front of the body portion 10, and battery holders 18 are located on either side thereof, the latter also serving as hand-grips and being shaped accordingly.

The body portion 10 further includes a "fire" button 20 at a convenient location on its top surface and a sighting eyepiece 22 on its rearmost surface. In order to reduce the size and complexity of the device, the sighting arrangement is combined with the transmitter optics, as shown in Fig. 3, such that the laser diode 24 and eyepiece 22 share the transmitter lens 14 by means of a beamsplitter 26 (preferably of the polarising type). The sighting optics are thus co-axial with the measurement laser, ensuring accurate sighting of the device, and at the same time providing a compact construction with the minimum of optical components. Fig. 3 also indicates the receiver lens 16 and detector (photo-diode) 28 of the rangefinder.

The electronics housing 12 is generally flat, and is positioned rearwardly of the lenses 14 and 16. A numeric keypad 30 and alphanumeric display 32 (preferably LCD, two by twenty characters) are mounted on the bottom surface of the housing 12, which is further provided with a data download socket 12, which is further provided with a data download socket 34 (preferably a serial, digital, bi-directional port) for downloading stored data from the device to a computer, printer etc (not shown) for display, storage and/or further processing.

Fig. 4 is a schematic block diagram of one embodiment of the invention adapted for use as a surveying device. The fire button, or trigger 22, keypad 30, display 32 and the output from the laser rangefinder, designated 36, are connected to a microprocessor 38, which is further connected to random access memory (RAM) 40. CMOS circuitry is preferably used to minimise power consumption. The device further includes an inclinometer 42, also having its output connected to the microprocessor 38, for measuring the angle at which the optical axis of the device is displaced from the horizontal.

The inclinometer is preferably an electrolytic angle

sensor (ie an electrolytic gravity or liquid level sensor) such as that used in the "TRIM" (Trade Mark) inclination sensor by Measurement Devices Limited. such a sensor is compact and accurate, and associated electronics compensate for temperature changes and power fluctuations. The laser itself is preferably a pulsed semiconductor laser operating in the eye-safe infra-red frequency band (wavelength preferably 0.9 microns).

The device preferably also includes a further numeric display 43, visible through the eyepiece and showing the distance measured and/or the current inclination of the device.

The rangefinder operates as follows. When the fire button 20 is operated, an electronic pulse generator 60 (Fig. 3) periodically drives the semi-conductor laser diode 24 to send out infra-red light pulses which are collimated and emitted by the transmitter optics. Via the receiver optics, part of the echo signal reflected back from the target strikes the photo-diode 28, which generates an electrical receiver signal. The time interval between the transmitted and received pulses is counted by means of a quartz-stabilised clock 62. The result is then output to the microprocessor 38, which performs the following functions:

- controls the measurement laser;
- avoids measurement errors;
- converts measured values to meters or feet;
- processes the measured values for data display storage and output;
- adjusts the measurement parameters (eg measurement resolution, unit of measurement, type of measurement, measurement program etc) by means of manually operated switches (not show), or programming via the keypad 30 or data port 34;
- performs internal self-check and zero-adjustment;
- controls/compensates for variations in supply voltage and operating temperature.

Depending upon the specification of the laser (and prevailing weather/lighting conditions), measurement to non-

cooperative targets up to 400 metres is feasible, and up to 10000 metres with cooperative targets (ie provided with retro-reflectors such as triple corner cubes), and accuracy of up to 1 cm can be achieved.

Other preferred features and specifications are as follow. The sighting optics preferably give a magnification of 8 x 21 and a field of view of 12 metres every 100 metres, are provided with a cross-hair reticle and allow focussing of plus/minus 5 diopters. The power consumption of the device is approximately 6 watts, and the power supply is preferably 12 "AA" size alkaline manganese batteries or nickel cadmium accumulators. A socket (not shown) may also be provided for connection of an external power supply, preferably 11 to 28 Volts D.C. The dimensions of the device might typically be approximately 260 mm by 165 mm by 70 mm, with a dust and splash-proof housing, and the weight approximately 2.1 kg (without batteries, 2.4 kg with batteries). A screw-threaded bush (not shown) may also be provided on the bottom of the device to allow tripod-mounting or the attachment of an accessory hand-grip.

Fig. 5 illustrates the use of the device in surveying a rock face 44. As shown, the operator 46 of the device positions himself adjacent to the face 44. With the device switched on, the display 32 prompts the user to enter reference data relating to the survey subject. In the present case, the rock face is surveyed by measuring the distances and corresponding angles of inclination for a number of points along a vertical profile 48, and this process is repeated for a plurality of profiles (surveyed from different positions 50) along the length of the face 44, the positions of the profiles being aligned with intended or actual borehole positions 52 in the case of bench drilling and blasting operations. Thus, the reference data might include the date, face reference number, instrument height (ie the observer's eye level above the ground) and a number indicating each particular profile.

Each measurement is made by sighting the device on the desired point, and pressing the fire button 20 to measure and record the distance and corresponding angle. As indicated

above, a set of consecutive measurements are made to describe the complete profile by panning the device down the face 44, and a number of such sets, describing the whole face 44, are made by repeating the process at known distances along the face 44. Marker cones 52 placed at the crest (or toe) of the face 44 may be used to provide reference measurements indicating the top (or bottom) of each profile. The boreholes 52 lie along a reference or "face" line 54, which is approximately parallel to the top edge of the face 44, and the markers 52 are positioned opposite the boreholes on a line normal to the face line 54. The offset distances of the markers 52 from the face line 54 (ie in the "measurement plane") may be measured, as may the spacing of the markers in a plane normal to the measurement plane. In this way the individual measurements and sets of measurements may be related to one another and to the actual or intended borehole positions and drilling angles, to provide a complete picture of the face 44 and its relationship to the boreholes. In more general surveying applications, similar markers and reference lines may be used to establish a co-ordinate reference system for the measured values.

The device may be used in conjunction with the "BORETRAK" (Trade Mark) borehole surveying system by Measurement Devices Limited, (described in International Patent Application No. PCT/GB88/00930), and suitable Mark software to provide a complete survey of a rock face for blasting operations. The software interpolates data downloaded from the rangefinder and BORETRAK device to allow numerical analysis and to provide graphic representations of the face and boreholes, including three-dimensional isometric views of the face, and vertical and horizontal sections showing the face in relation to the borehole positions etc.

In a typical blasting survey, the laser rangefinder (either the present hand held device or the existing Quarryman device) is used to determine the spatial coordinates of an array of points on the surface of the rock face. The software can then produce a three-dimensional model of the rock face, from which it may generate isometric views from any viewpoint,

and vertical and horizontal cross-sections, together with associated numerical data. Once the face has been surveyed, the computer model may be used in selecting borehole positions, spacings and angles, and may calculate the minimum burden, face height, slope height, profile cross-sectional area, hole coordinates and face volume for a given set of borehole parameters, and may provide corresponding isometric, vertical and horizontal profile views as shown in Figs. 6, 7 and 8 respectively. Once suitable borehole parameters have been selected, the holes may be drilled and surveyed using the BORETRAK system referred to above. Details of the actual holes can be compared with their intended parameters and the actual minimum burdens and face volumes recalculated. Potential problems relating to critical borehole-to-borehole or borehole-to-face profile convergences can by automatically highlighted on the graphical representations if they fall outwith acceptable limits. Tabulated numerical data can also be generated if desired and highlighted in the same way.

The hand held device described herein is more compact and less expensive than the existing Quarryman system, but is necessarily somewhat less accurate in absolute terms. If greater accuracy is required, however, it can be tripod-mounted, and the tripod may be provided with a horizontal angle sensor to provide a system which operates in substantially the same manner as Quarryman. Slightly modified electronic data logging equipment and software would also be required.

Laser rangefinders may also be used in a manner analogous to the blasting survey method described above for surveying stockpiles of material. Figs 9 and 10 show examples of an isometric view and plan contour plot which might be generated from a set of spatial coordinates in such a case. The volume of the stockpile can be calculated and hence the tonnage contained therein estimated from the average density of the material in question.

The rangefinder described above can easily be adapted to measure the speed of moving targets, by altering its operation to measure the time elapsed between two successive distance

measurements such that the speed of the target can be calculated from the change in distance and elapsed time. Such a device could be used, for example, to measure the speed of vehicles, and would provide significant advantages over Dopper-effect radar guns currently used by traffic police which are subject to problems of confused readings from multiple targets, limited accuracy and ease of detection by motorists. A laser rangefinder as described herein avoids these problems since the measuring beam is very narrow and is optically aligned with the approaching vehicle, is inherently more accurate, and can only be detected if the measuring beam is intersected, by which time the speed has already been recorded.

CLAIMS

1. A laser rangefinding device, comprising a self-contained unit consisting of a laser for transmitting a laser signal towards a target, detector means for detecting the reflection of said signal from the target, microprocessor means for measuring the elapsed time between transmission of the signal and detection of the reflected signal and for calculating the distance of the target from the device, memory means for storing a plurality of calculated distances and other data associated therewith, optical sighting means for aligning the laser signal axis with the target, input means for inputting reference data relating to the measured distances, and visual display means for displaying measured distances and other data, the unit being of a size and weight suitable for hand-held use.

2. The device of claim 1, further including an inclinometer for measuring the inclination of the device to the horizontal, the memory means being adapted to store the inclination associated with each measured distance.

3. The device of claim 2, wherein the input means preferably allows the input of reference data relating to the subject being surveyed and the height at which the device is held in use.

4. The device of claim 2 or claim 3, wherein the inclinometer is an electrolytic liquid level sensor.

5. The device of claim 1, further including means for measuring the elapsed time between successive distance measurements taken from a target, and for calculating the speed at which the target is moving from the difference between the two measured distances and the elapsed time therebetween.

6. The device as claimed in any preceding claim, including a main body portion incorporating the laser, detector and sighting means, and having a transmitter lens, associated with the laser, and a receiver lens, associated with the detector, disposed side-by-side, with battery housings adapted to receive batteries to power the device located on either side

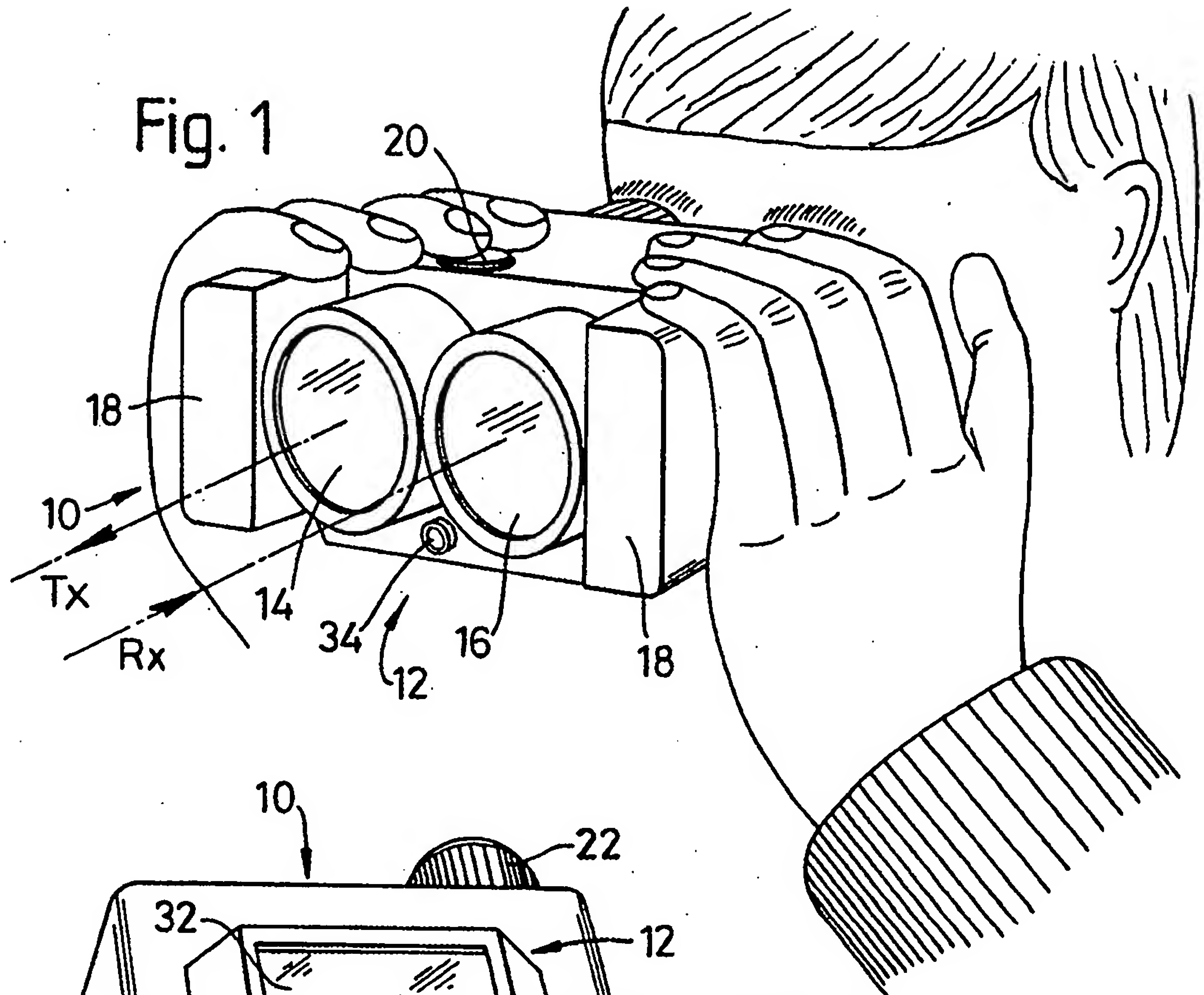
of the lenses and adapted to constitute hand-grips.

7. The device as claimed in any preceding claim, wherein, the data input means is a keypad which, together with the visual display, is located on the underside of the main body portion.

8. The device as claimed in any preceding claim, wherein the sighting arrangement includes an eyepiece located in a rear surface of the main body portion, and adapted to sight through the transmitter lens along the signal axis.

9. The device of claim 8, wherein a second visual display is provided, which is visible through the sighting eyepiece.

Fig. 1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Rx
14
34
12
16
18

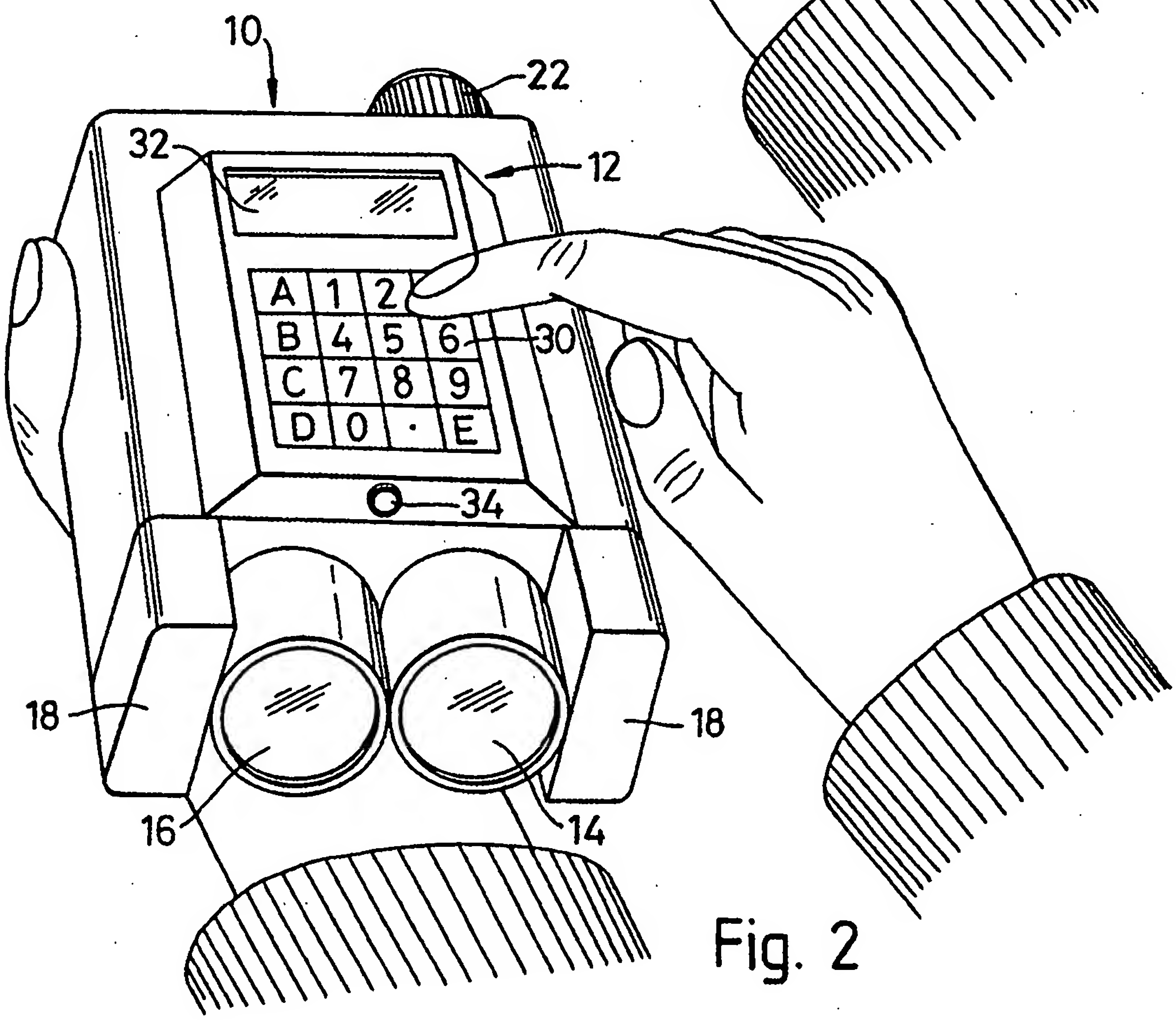
10
22
32
12
A 1 2
B 4 5 6
C 7 8 9
D 0 · E
30
34
18
18
16
14

Fig. 2

2/6

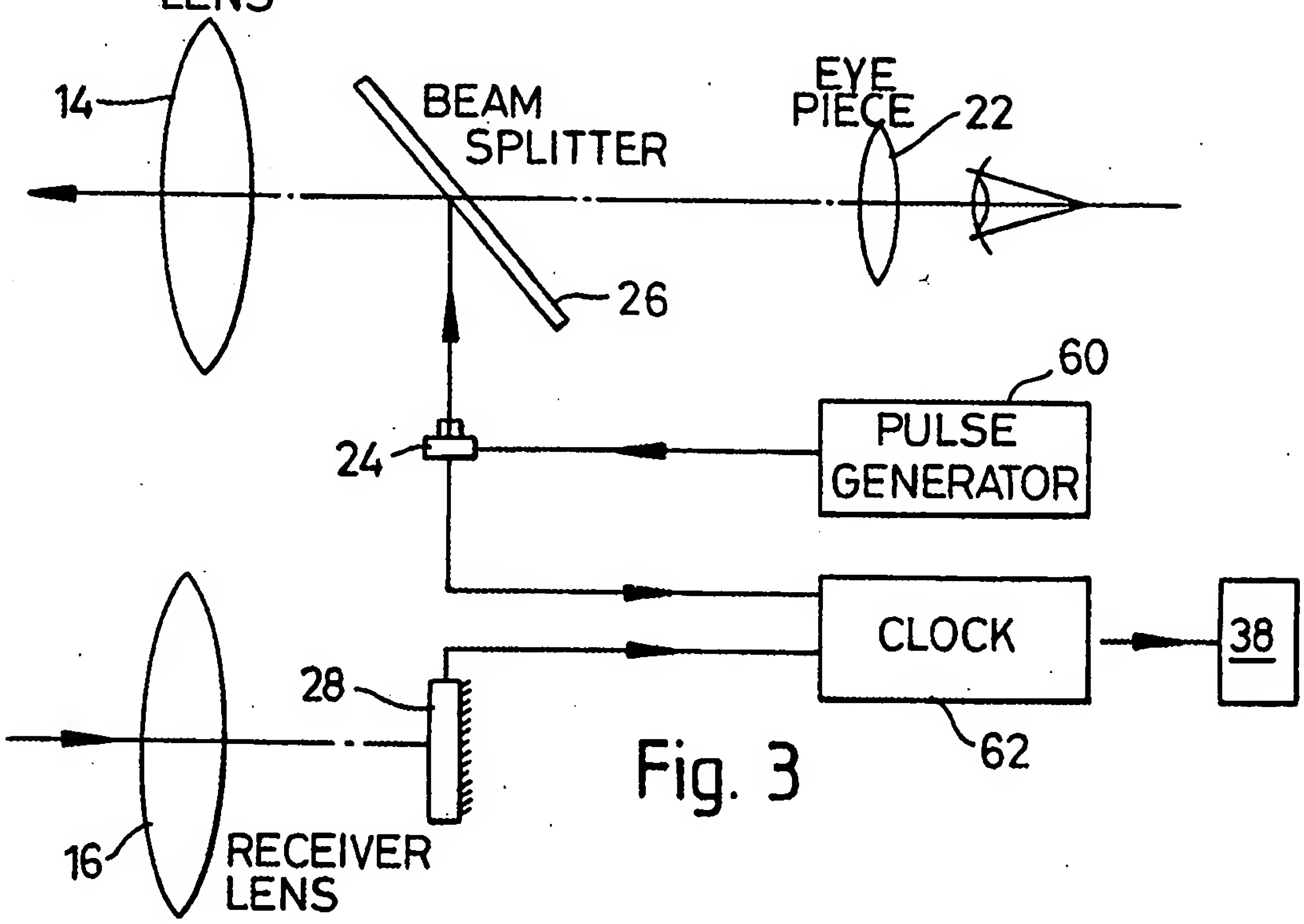

Fig. 3

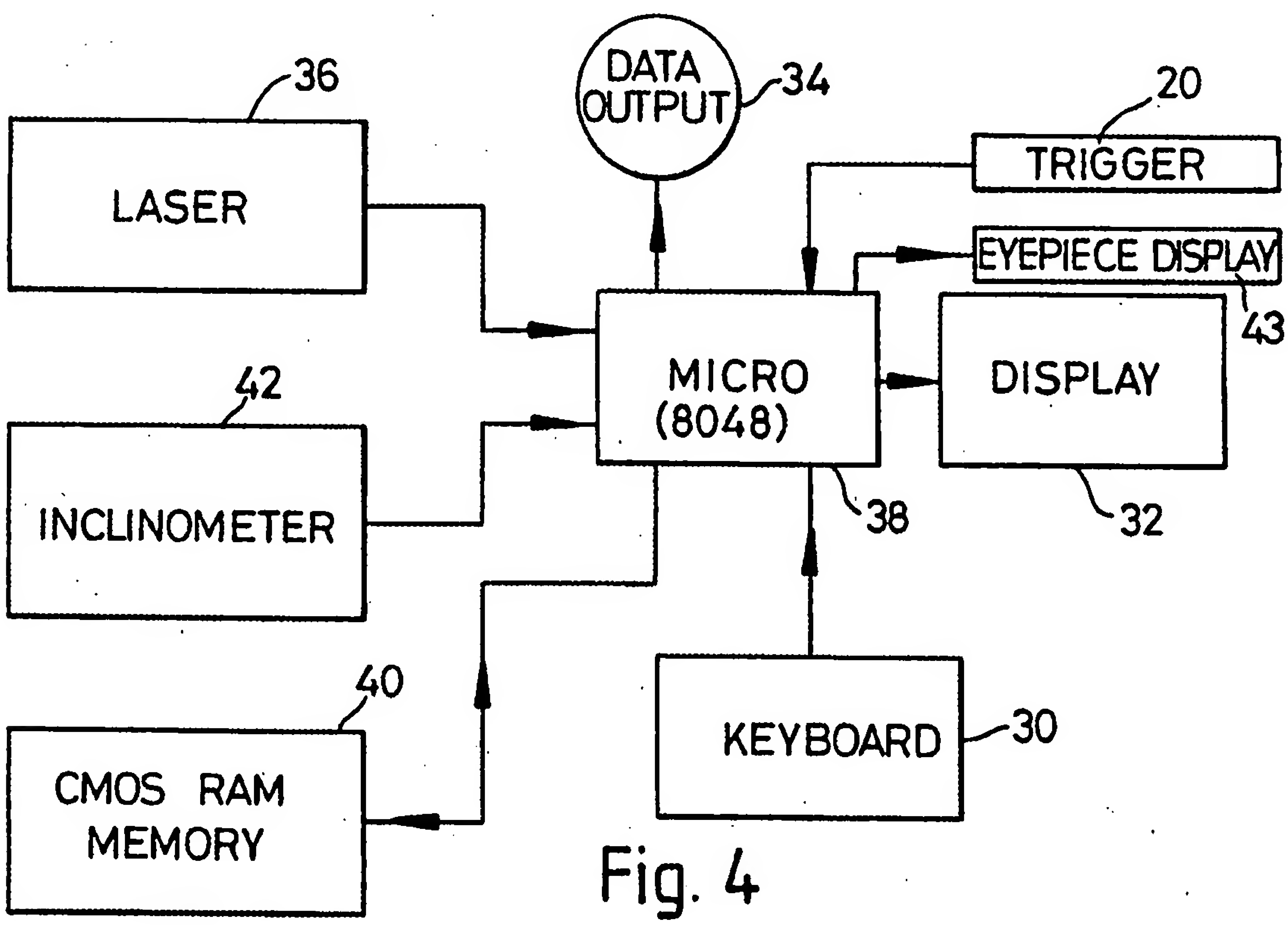

Fig. 4

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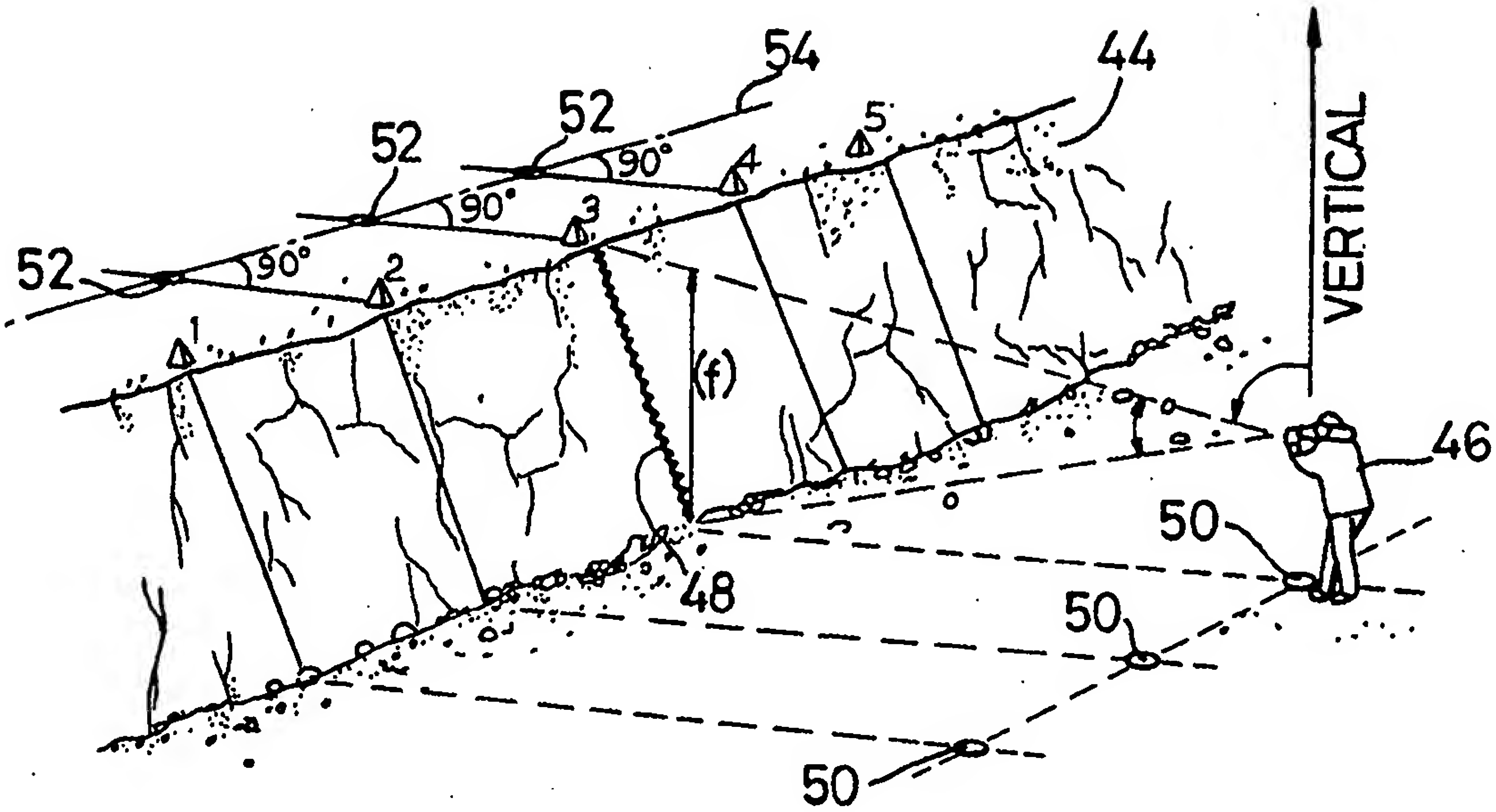

Fig. 5

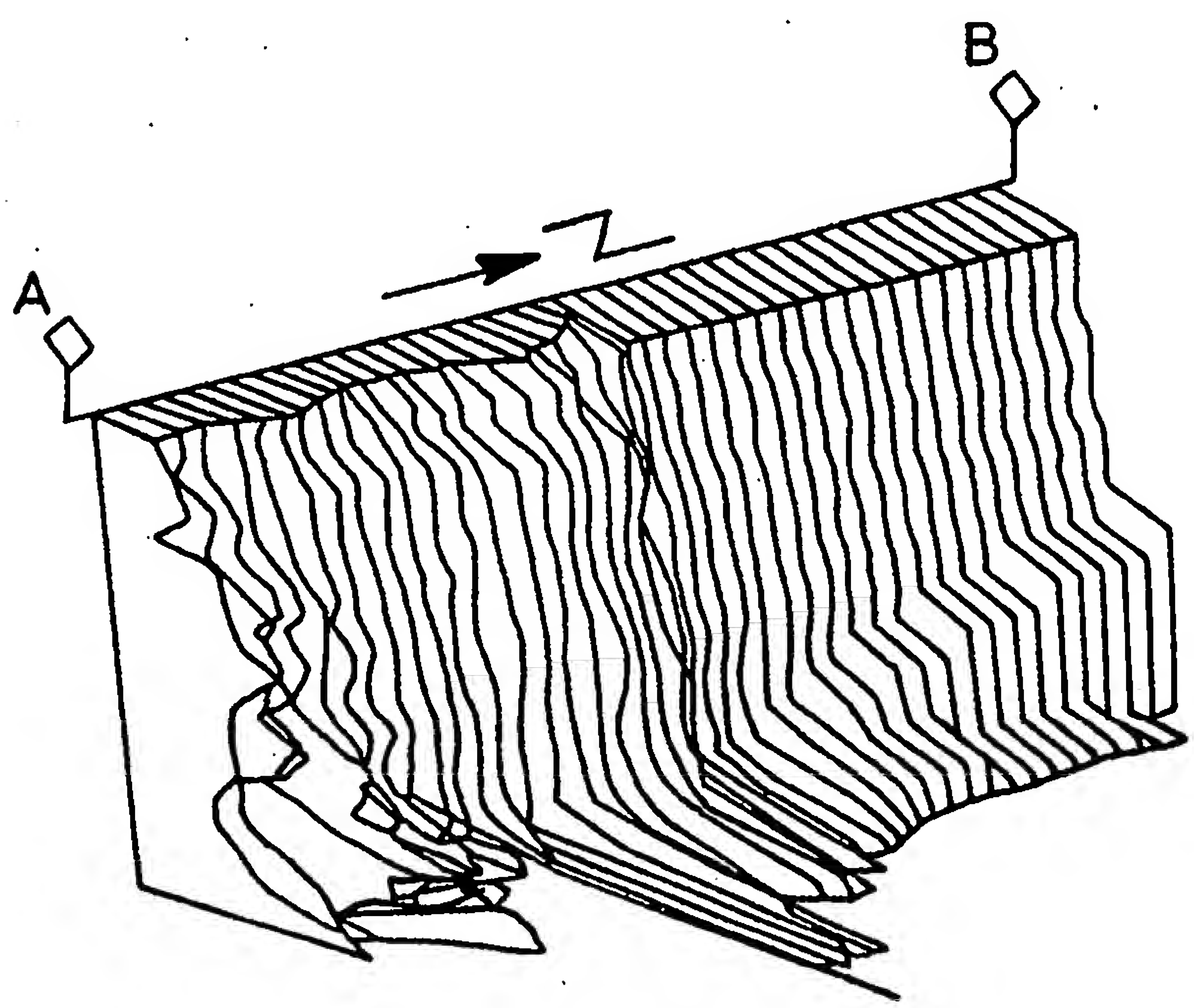

Fig. 6

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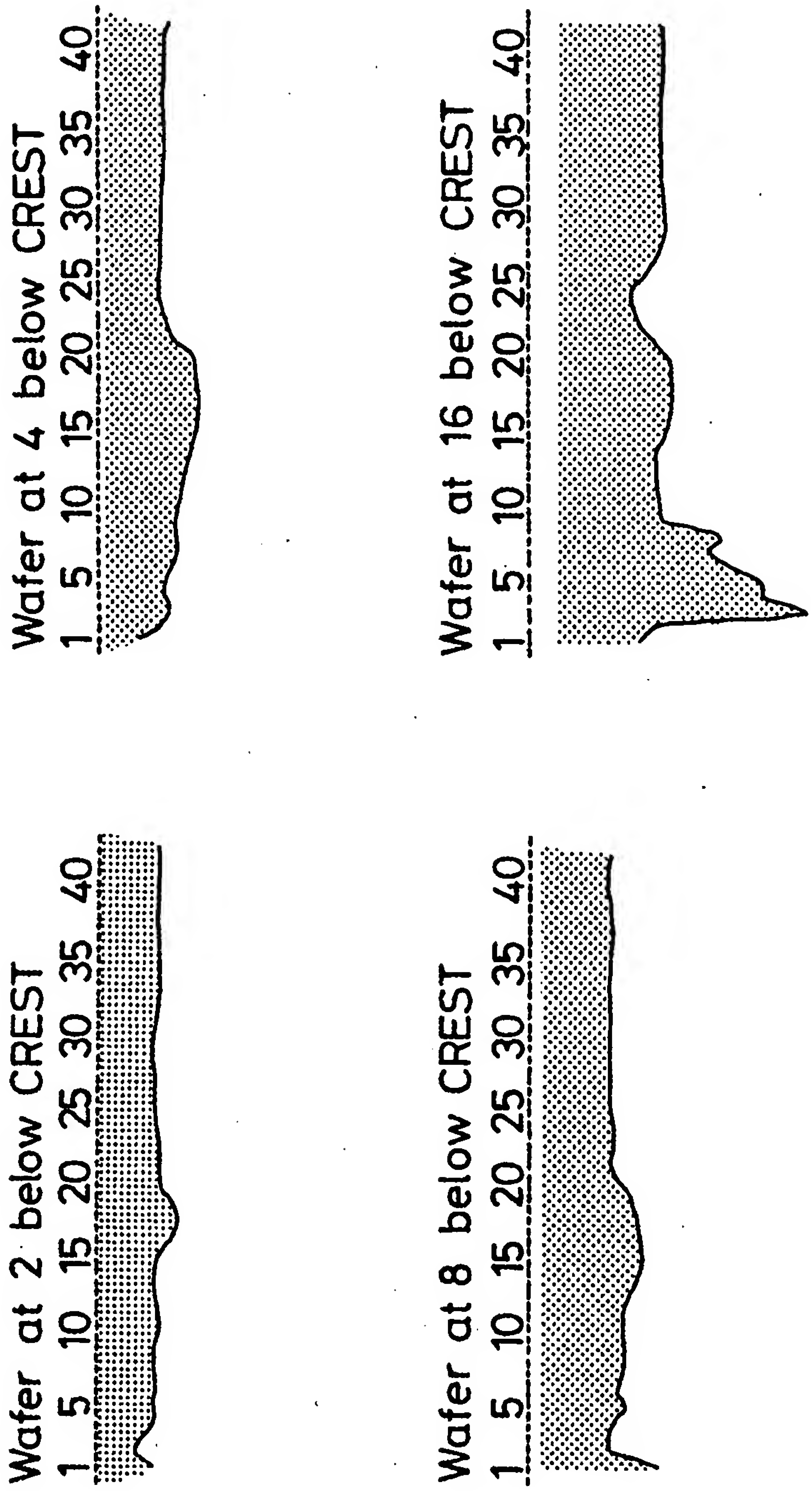

Fig. 7

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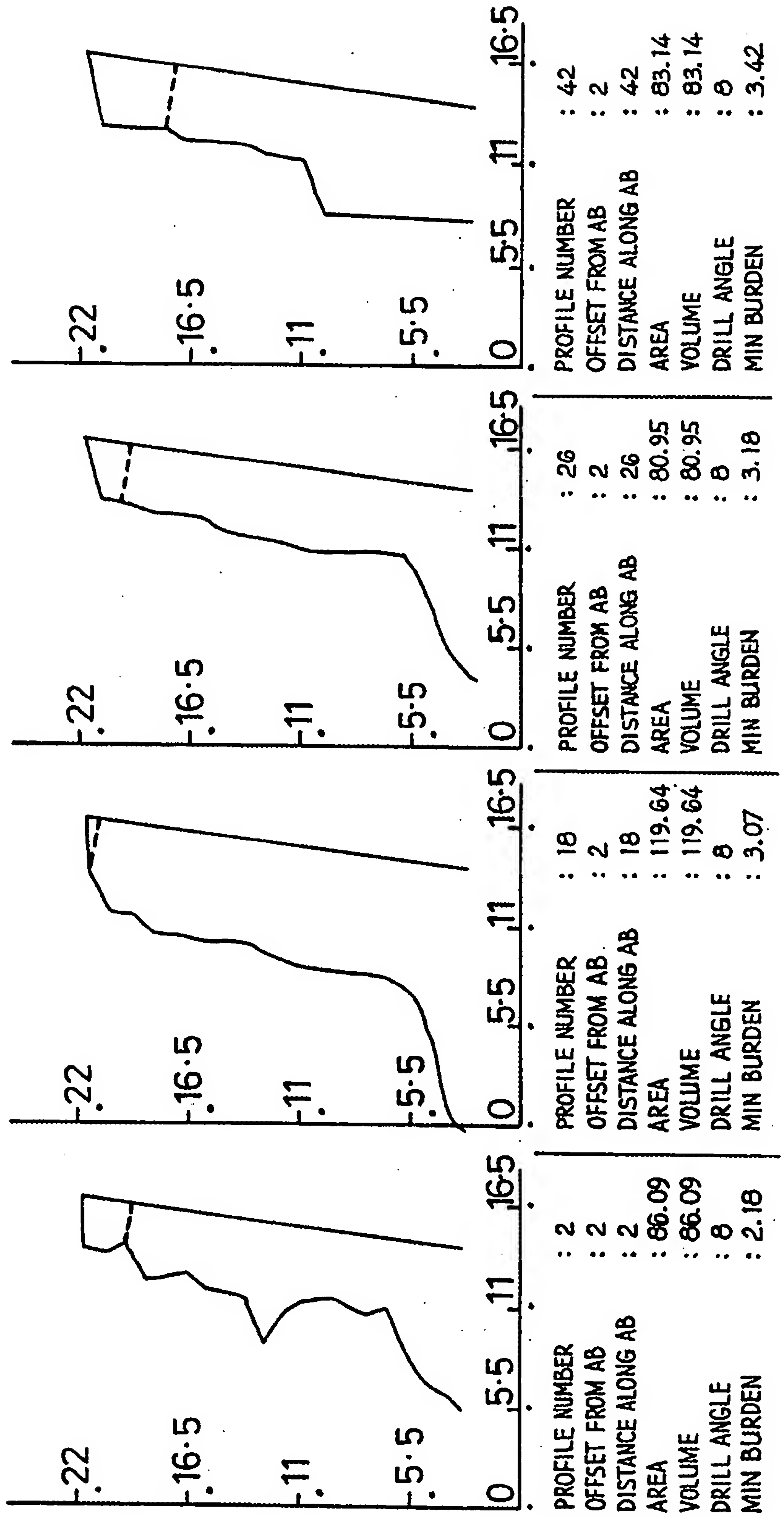
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11
5·5
0
5·5
11
16·5
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DISTANCE ALONG AB : 2
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MIN BURDEN : 2.18
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OFFSET FROM AB : 2
DISTANCE ALONG AB : 18
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VOLUME : 119.64
DRILL ANGLE : 8
MIN BURDEN : 3.07
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DISTANCE ALONG AB : 26
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PROFILE NUMBER : 42
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Fig. 8

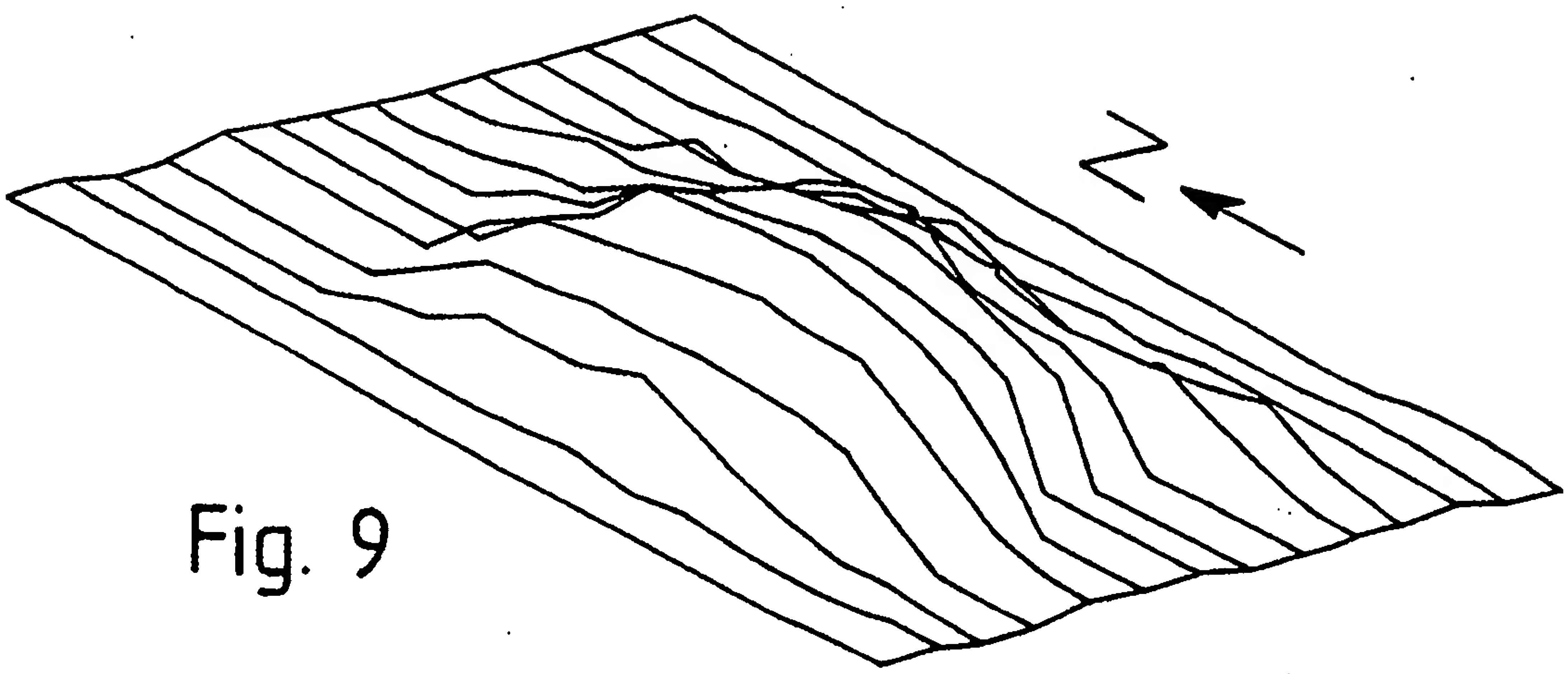

Fig. 9

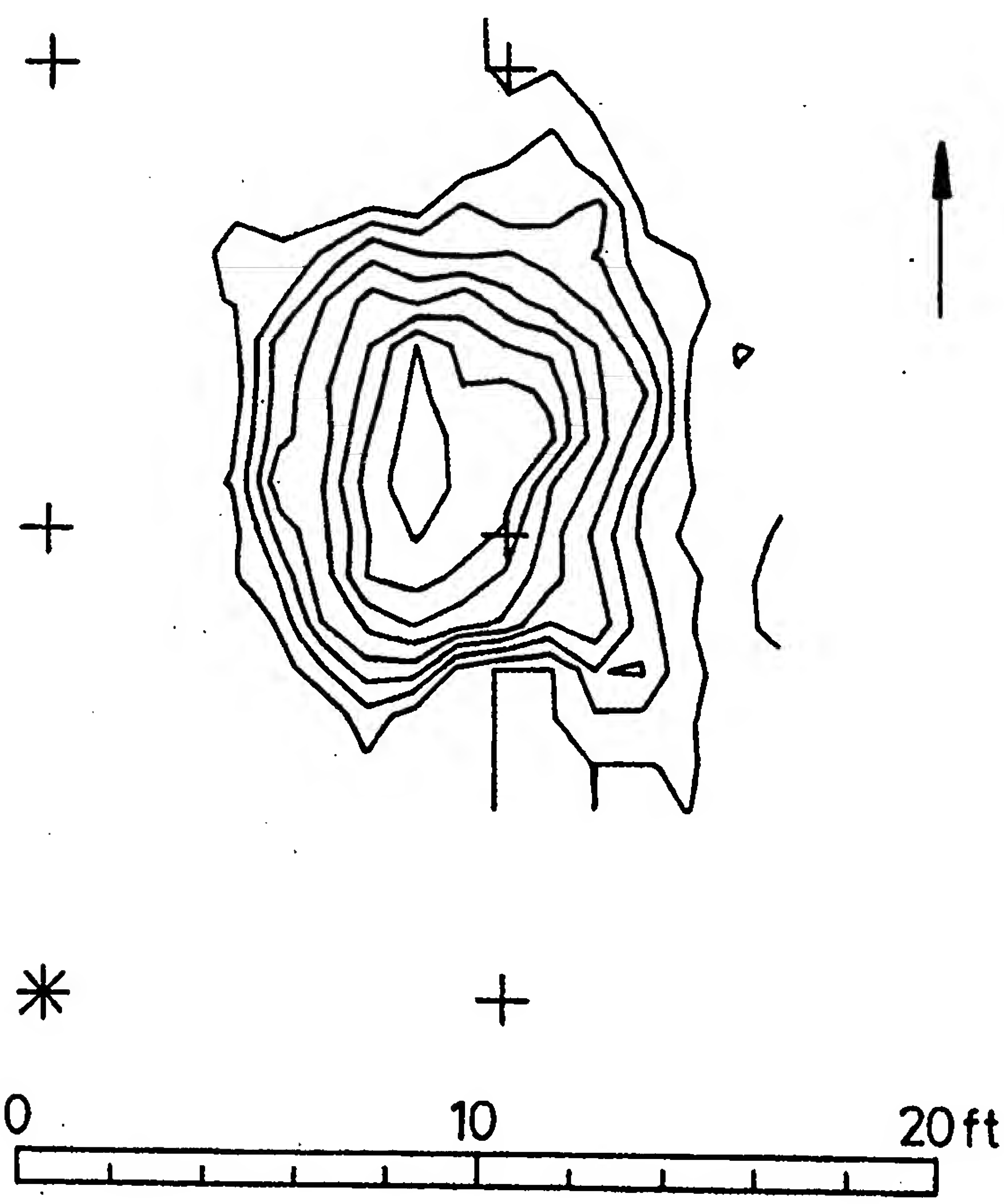

Fig. 10

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